

Low-Frequency Variability and Cross-Front Exchange Processes at Shelf-Break Fronts

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LONG-TERM GOALS

The long-term goal of this project is to understand the physical processes that control the low-frequency variability of and exchange of water masses, properties, and materials across shelf-break fronts.

OBJECTIVE

The near-term objectives are to gain fundamental insights into the role of mixed baroclinic / barotropic instabilities and the bottom boundary layer in the evolution of the shelf-break front density structure, eddy formations, and cross-front exchange.

APPROACH

A high-resolution primitive equation numerical model is being applied to a series of idealized experiments representative of typical winter and summer conditions found at the shelf-break in the Mid-Atlantic Bight. Tracers (both passive and active) and simulated Lagrangian parcels are used to estimate the exchange across the front. The sensitivity of the exchange processes to physical parameters (topography, stratification, friction) is being investigated. The role of the barotropic along-shelf flow and the related bottom boundary layer on the maintenance of the front and cross front exchange is under study.

Numerical calculations are complemented by theoretical estimates of eddy heat and tracer transports in frontal regions.

WORK COMPLETED

The Semi-Spectral Primitive Equation Model (SPEM) has been configured in open boundary and periodic domains. Calculations have been carried out for both summer- and winter-like conditions. Various models for a barotropic shelf current and baroclinic shelf-break front current are being tested. Diagnostic routines in both isopycnal and frontal coordinates have been developed.

A theory which predicts the parameter dependence and the amplitude of the eddy heat flux across narrow frontal regions has been developed (Spall and Chapman, 1998). The theory has been tested with primitive equation numerical model calculations representative of the spin-down of a baroclinic front and the equilibration of local surface cooling by lateral eddy fluxes.

RESULTS

A theoretical estimate of the cross front heat flux carried by baroclinic eddies has been developed and tested. The parameter dependence predicted by the theory is the same as previous estimates derived from scaling arguments, however the present approach also provides a quantitative estimate of the amplitude of the eddy heat flux and a clearer physical understanding of the dynamics that control and lateral heat transport by baroclinic eddies.

Numerical calculations of typical shelf-break frontal structures have shown that, in the absence of bottom friction, the foot of the front propagates quickly up-slope into the shelf region. Realistic values of bottom friction suppress this unstable bottom trapped mode such that the instabilities of the shelf-break front are surface intensified but not of sufficient strength to destroy the sharp density gradients marking the front. The further addition of a barotropic along shelf flow adjacent to the front results in a bottom boundary layer transport offshore towards the shelf break. This transport detaches from the bottom at the foot of the front, consistent with previous modelling results and more recent observations. The density gradients at the foot of the front are enhanced by this convergent flow.

IMPACTS/APPLICATION

Understanding the dynamics of lateral eddy heat fluxes and ageostrophic velocities in these idealized situations provides a building block for understanding observations and for parameterizing the role of eddy fluxes in more complex flows.

RELATED PROJECTS

The frontal processes studied here are relevant to a number of other ONR, NSF and NOAA programs. The ideas developed during this funding period have been applied to the analysis of data in the ONR funded shelf-break PRIMER experiment by Glen Gawarkiewicz (WHOI) and Bob Pickart (WHOI). The theoretical model of eddy heat fluxes has also aided the analysis of Dave Chapman and Glen Gawarkiewicz (WHOI) in their NSF funded study of dense water formations in coastal polynyas. Tom Weingartner (Univ. Alaska) has also found close agreement between the theoretical estimate of eddy heat fluxes and recent observations funded by ONR in the western Chukchi Sea.

REFERENCES

Spall, M. A. and D. C. Chapman, 1998: On the efficiency of baroclinic eddy heat transport across narrow fronts, *Journal of Physical Oceanography*, 28, 2275-2287.